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THE DIAL GAUGE AND ITS USE

Report by Dr. Geo. Schlesinger, Director of Research Department of the Institution.

THE ordinary use of the dial gauge is as a comparator—i.e., for the measurement of small differences of dimensions. An important part of its application is the acceptance tests on machine tools. For example, we can measure the concentricity of various elements of a machine spindle, directly, (Fig. 1 a, b, c), indirectly by putting a taper mandrel into the bore (Fig. 2). We can measure surfaces by comparing their flatness or parallelism with another surface as in Figs. 3 and 4, or in vertical positions by comparing with a square as in Figs. 5 and 6.

The permissible errors called for on standard machine tool acceptance charts may range from 0.0004 in. (0.01 mm.) to 0.002 in. (0.05 mm.).

In a single component—e.g., the race of a ball-bearing, the permissible tolerances are in the same range.

In all these cases the important measuring feature is that the dial gauge keeps its position on the surface of comparison unchanged during the whole measuring operations. It may rest stationary all the time (Figs. 1, 2, and 5), whereas the carriage (Fig. 3a) or the quill to be checked (Fig. 3b) may be sliding, or it may itself move with the spindle or the stand as a whole (Fig. 6). In all these cases the fixation points of the stand up to the clock (A, B, C) (Fig. 7), remain untouched.

We will denote these tests as made with the stationary dial gauge. They have the great advantage of using the simple, accurate and easily manageable dial gauge in such a way that possible imperfections of the stand do not influence the accuracy of the measurements.

The scope of the dial gauge is unusually large, depending on the ranges of movement of the plunger which may vary between 0.2 and 0.5 in. (5 and 12 mm.) according to design. There is usually a revolution counter to record the number of revolutions of the pointer, and dials may be graduated in 25, 40, 50, or 100 divisions.

The correct functioning of a gauge depends upon: (*a*) repeatability of reading; (*b*) accuracy of reading. The gauge should repeat its reading under all ordinary methods of operation to within one-fifth of one unit division (B.S.I. Specification on Dial Gauges—1939).

It is advisable to use the clock always at approximately the same plunger position, so that the pressure of the spring remains the same

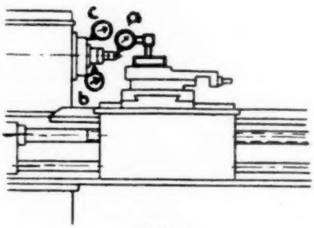


Fig. 1.

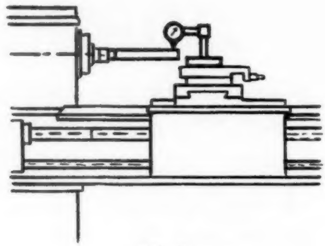


Fig. 2.

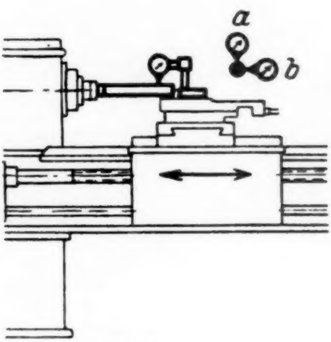


Fig. 3a.

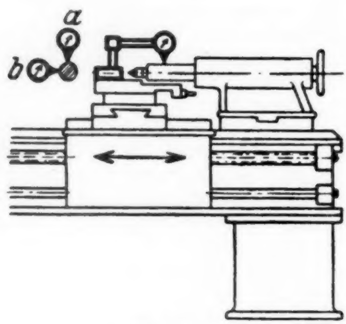


Fig. 3b.

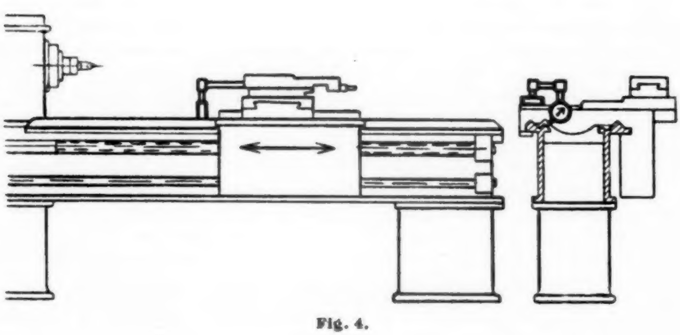


Fig. 4.

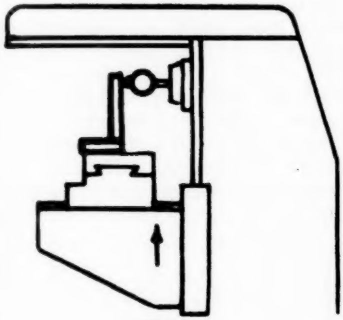


Fig. 5.

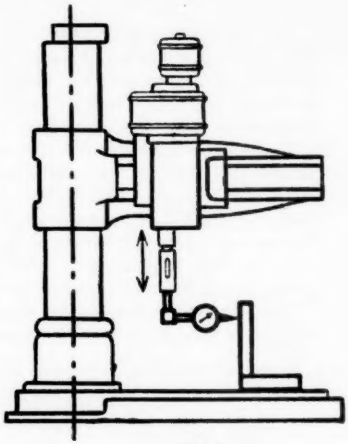


Fig. 6.

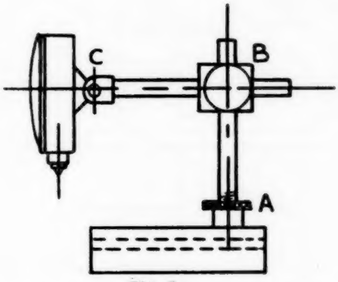


Fig. 7.

on the plunger, otherwise the measurements at different times and places are not comparable even with the same gauge.

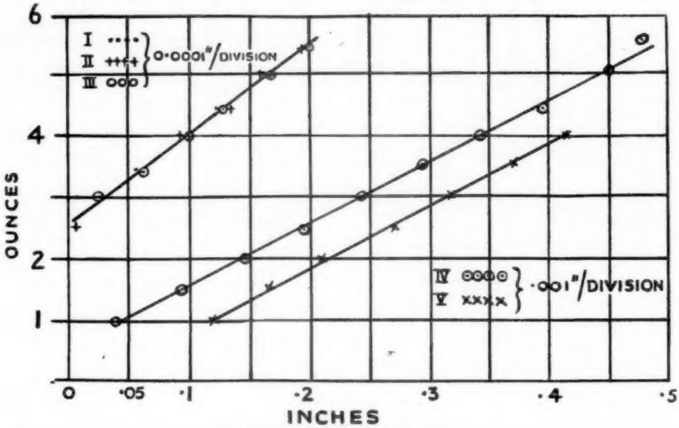
To prove this, five-dial gauges of good British make have been tested with the following characteristics :—

No.	Accuracy in.	Total Rev. of Pointer	Range of Plunger in.	Range of Plunger mm.	Division Unit	Division Number	Division Graduation	Dia. of Dial	Weight oz.
I	0.0001	22	0.2	5	0.0001	±50 (100)	full	2 in.	6¾
II	0.0001	22	0.2	5	0.0001	100	full	2 in.	6½
III	0.0001	22	0.2	5	0.0001	±50 100	full	2 in.	6⅛
IV	0.001	12	0.5	12.7	0.001	±30 40	full and halves	2 in.	6¼
V	0.001	5	0.5	12.7	0.001	±50 [illegible]	full	2 in.	6½

The plunger springs were now loaded and unloaded from zero to maximum and back. All the graphs (Fig. 8) have, vertically, the pressure in ounces and, horizontally, the actual stroke of the plunger in inches (not the numbers of revolutions of the division pointer) in order to have the same basis of comparison.

To be sure that the dial gauge had a good sensitivity three-dial gauges of 0.0001 in. per division have been checked over their full range of about 20 revolutions = 0.2 in. (5 mm.). The graphs prove that the three instruments (I, II, III) are really interchangeable. The spring pressure varies in proportion to the compression, from 3 oz. for the beginning of the reliable movement of the plunger (three revolutions of pointer) to 5½ oz. at the 20th revolution.

The total deviation of the three instruments compared with each other was less than ⅛ oz. for the same position.



Checking of five-dial gauges.

I, II, III have 0.0001 in. division. IV, V have 0.001 in. division.

Fig. 8.

The two coarser instruments (IV, V) of 0.001 in. reading per division have lighter springs, which is often very useful. The movement begins with about 1 oz. pressure for 0.04 in. stroke of plunger, after the first half revolution and ends with 4 and 5 oz., respectively for 0.4 in. and 0.5 in. (10 and 12 mm.) total stroke of plunger. The law of the spring (stress proportional to compression) is again fulfilled, but gauge No. V has a much lighter spring than No. IV. For 0.2 in. depth we read 1¾ oz. load for No. V, and 2¾ oz. for No. IV.

A good mean plunger position would be between 3½ to 4½ oz. for gauges Nos. I, II, and III, and 1½ to 2½ oz. for gauges Nos. IV and V.

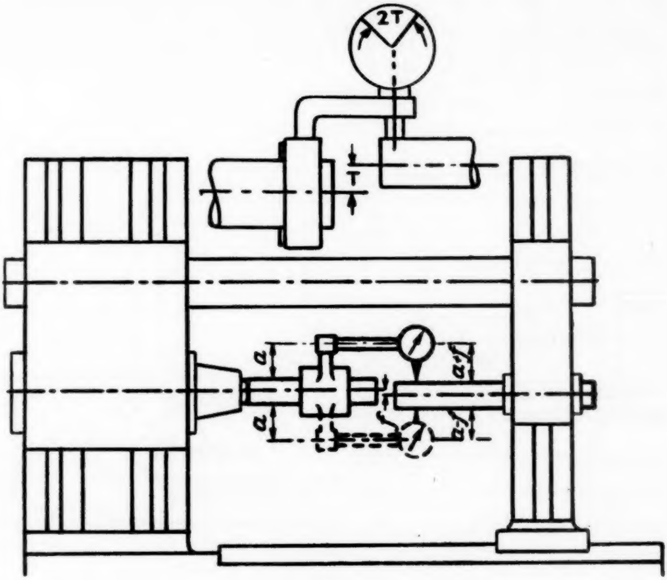


Fig. 9.

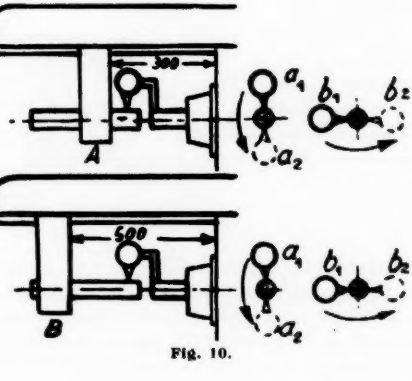


Fig. 10.

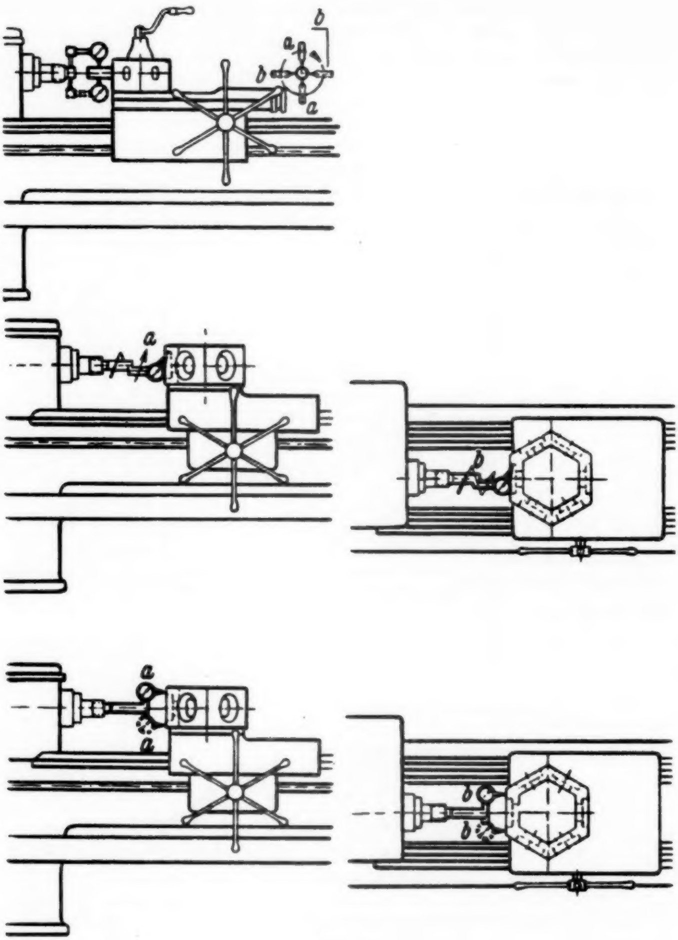


Fig. 11.

As the order of accuracy depends on the position of the plunger, these graphs are a good guidance in selecting this position according to the desired spring pressure, which has an influence on the deflection of the supporting arms of the stand.

The arms of test indicator stands are generally too weak. The deflection of the arm is made by the weight of the dial gauge which is about $6\frac{1}{2}$ oz. (in our case) ± another $1\frac{1}{2}$ to 6 oz. spring pressure. These forces bend the arm considerably and in particular are of

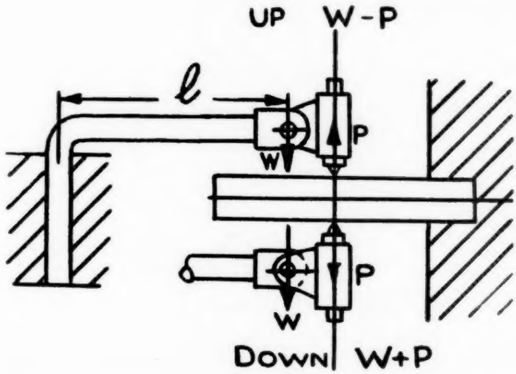


Fig. 12.

decisive influence when the stand of the gauge is no longer stationary but used, by causing it to rotate on a horizontal axis (Fig. 9, 10, 11). In these cases the plunger is changing its vertical position from up to down, when the dial gauge is swung round the axis which is to be checked, represented in the illustrations by (1) a rigid stationary mandrel in the cutter arm support (Fig. 9), (2) overhanging arm (Fig. 10), (3) turret (Fig. 11), etc.

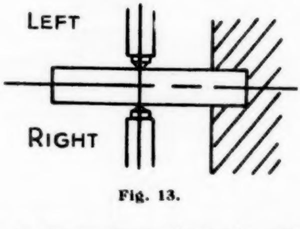
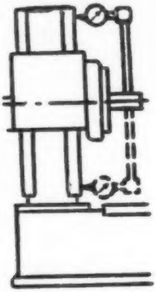


Fig. 13.

Again in Fig. 12, in the upper position the weight W of the clock of 6 oz. downward may be equalised by the same pressure P of the spring upward : $6 - 6 = 0$. The deflection of the arm of a length l is then zero. In the lower position weight + pressure deflect the arm with $6 + 6 = 12$ oz.



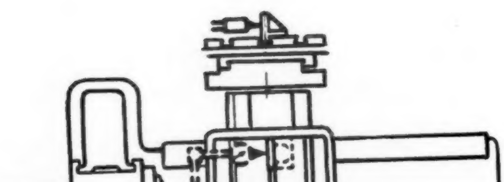


Fig. 14.

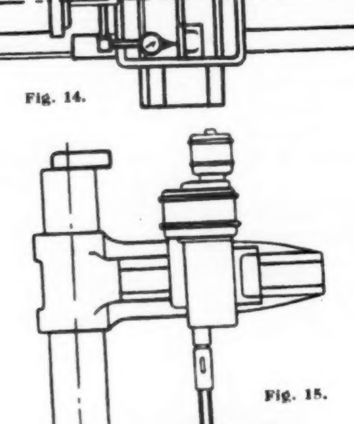


Fig. 15.

In Fig. 13 when horizontal measurements are being taken, we have the same actions, but spring and weight work in two planes perpendicular to each other. The swing-round method is faultless for all purely horizontal or vertical measurements (Figs. 14, 15).

Deflections were measured by putting the necessary weights directly onto the arm (Fig. 16) and by measuring the deflection by

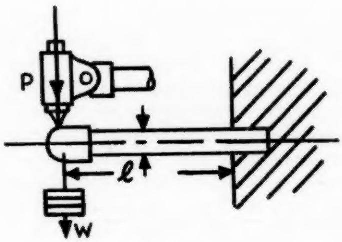


Fig. 16.

means of a dial gauge, clamping the original stand column in a heavy vice. The table gives the comparison between a solid steel bar of d = ½ in. dia. and l = 6 in. length, and a hollow brass tube of ⅞ in. dia., and 6, 8, and 10 in. length.

Bar	Dia. in.	Length in.	Weight oz.	Load in Ounces 1	2	3	4	5	6	8
Solid Steel (+ Head)	½	6	185	1.5	2	3.5	6	7.5	10	14
Brass Tube	⅞	6	160	0.8	2	3.5	4	5.5	7.5	9.5
		8	205	1.2	3.4	5.4	7	9	11	14.7
		10	240	2.5	5.6	8.2	11.4	14.2	18	24

Bar	Dia. in.	Length in.	Weight oz.	Load in Ounces 10	12	14	16	18	20	24
Solid Steel (+ Head)	½	6	185	16	20	24	28	32.5	35	42
Brass Tube	⅞	6	160	12	14	16	18	20	23	27
		8	205	18.2	22.2	26	30	34	38.5	46
		10	240	30	36	42	48	54	61	74

TABLE I—DEFLECTION IN 0.0001 in.

Table I shows that a weight of 12 oz. causes 20 divisions = 0.002 in. deflection and for 10 oz., 0.0016 in. This would be double or 1.6 times the admissible tolerance for the capstan lathe or the

milling machine. Consequently the swing-round method with a bar of steel of $\frac{1}{2}$ in. diameter and only 6 in. length stressed by the weight of the ordinary dial gauge ($6\frac{1}{2}$ oz.) plus a mean spring pressure of $3\frac{1}{2}$ oz. = 10 oz. corresponding to 0.0016 in. deflection, is useless.

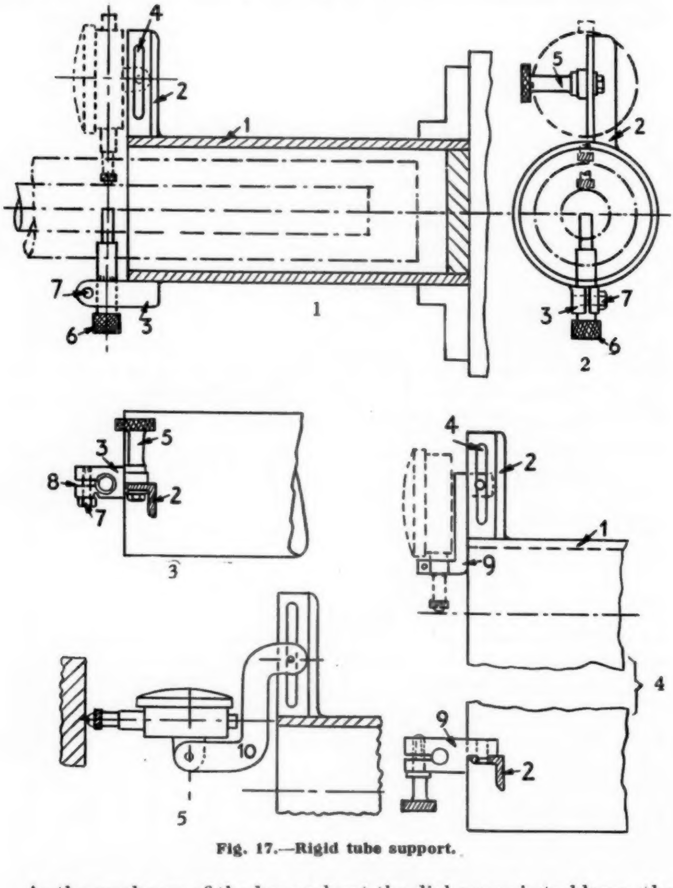


Fig. 17.—Rigid tube support.

As the weakness of the bar and not the dial gauge is to blame, the solid steel bar has been replaced, for a second test, by a brass tube of $\frac{7}{8}$ in. diameter, $\frac{3}{4}$ in. bore and approximately the same weight. The deflections are measured for different lengths of 6 in., 8 in., and 10 in

Table I shows that the deflection for 10 and 12 oz. stress, respectively is less than that of the steel bar, but still too great : 0.0012 in. to 0.0014 in., because the brass tube is not resistant enough against the bending stress.

The proof, however, is really furnished that the ordinary one-sided arm of ½ in. is wrong for the swing-round method.

Therefore, the design of the arm has been principally changed according to Fig. 17, 1 to 3. It consists of a steel tube (1) of 3½ in. diameter outside and 3 in. bore, 10 in. long, an angle piece, (2) or two at right angles welded, to avoid any joint, with a slot, (4) for the lug of the gauge, long enough to give the dial plunger the scope from the centre (zero) to 3½ in. diameter. To load and unload the tube at full length and to check the accuracy of the dial gauge in position as well as the rigidity of the whole design a threaded block (3) is welded to the tube opposite to the angle piece, being the same weight. Thus, the tube is fully balanced in itself and in any position.

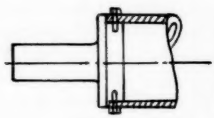


Fig. 18.

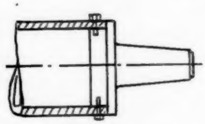


Fig. 19.

The dial gauge can be fastened by a lug and screw (5) or by the stem (9, Fig. 17, 4), or by an angle piece (10, Fig. 17, 5). The micrometer screw (6) can be locked by screw (7) which closes slot (8) ; it can be used instead of the dial gauge for measuring purposes.

The tube allows testing mandrels of any diameter up to 2¾ in. to enter its bore to the full length of 6, 8, 10, and 12 in. There would be no difficulty in enlarging the tube diameter if necessary. The tube is a simple rigid holder only. It may be left rough on the exterior and interior surfaces. It is either clamped directly on a self-centring chuck on the spindle nose or taken by a cylindrical or taper adapter for automatic screw machines, milling machines, etc. (Figs. 18 and 19).

Such an apparatus has been checked with a 0.0001 in. dial gauge, fastened to the spindle of a capstan lathe with the pointer in the upper position, and also in the lower position, first increasing, then decreasing the load from 1 to 48 oz., by applying weights directly to the head of the checking screw (6).

The Table II gives the results which met all our expectations.

The comparison with the solid steel bar of ½ in. diameter and the brass tube of ⅞ in. diameter proves the striking superiority of the new design.

Weights of 8 to 10 oz. cause negligible deflections ; 12 oz. = weight of clock + strongest pressure of spring, create a deflection

Instrument	Dia. in.	L'gth	Stress in Ounces								
			4	6	8	10	12	16	24	32	48
Solid Bar of Steel	½	6 in.	6	10	14	16	20	28	42	—	—
Hollow Bar of Brass	⅞ by ⅝ bore	6	4	7.5	9.5	12	14	18	27	—	—
		8	7	11	14.7	18.2	22	30	46	—	—
		10	11.4	18	24	30	36	48	74	—	—
Concentric Steel Tube	Downward 3½	10	0.1	.2	.4	.5	.7	1.0	1.7	2.2	3.9
	Upward 3½	10	0.1	.2	.4	.6	.7	1.0	1.8	2.3	3.8

TABLE II—DEFLECTIONS IN TEN-THOUSANDTHS INCHES

0.00007 in. only. A load of even 1 lb. bends 0.0001 in. = one division only; 3 lb. show 3.9 ten-thou. The influence of the position, up or down, is fully eliminated. The tube is practically rigid. The application of the apparatus for checking a well-levelled capstan lathe showed good concentricity of spindle axes with mandrel in the tool hole in a "warmed up" state of the machine tool, and 0.0025 in. lower in "cold state," which confirms actual practice.

Therefore, we can use the dial gauge with full certainty for rotatable reading of the above-mentioned difficult kind. The simplicity and convenience of reading actual errors (which is doubled by the swing-round method, c.f. Fig. 9) make the dial gauge method of test equivalent to the best others.

The advantages of this rigid and simple swing-round attachment in combination with the dial gauge are :—

(1) Perfect rigidity against bending and torsion by weight of the heaviest dial gauges (6 to 8 oz.), plus the heaviest pressure of the plunger spring (6 to 8 oz.).

(2) No different readings in any position on account of the great rigidity of the tube, in particular in the upper and lower vertical position of the gauge (the swing-round positions).

(3) Certainty of full repeatability of readings.

(4) Simple checking of the dial gauge itself in any radial position by suitable checking means.

(5) Wide range of adaptability to the various diameters of mandrels from zero to almost the bore of the tube.

(6) Independence of length of test mandrel (12 in.) which can enter the tube to its full length.

(7) Light weight of the simple design (6 lb.).

(8) Easy mounting and dismounting of the attachment by any self-centring or ordinary chuck, cylindrical or taper adapter corresponding to the shape and design of the spindle nose of the machine tool.

PRODUCTION OF OIL ENGINE CASTINGS.

Paper presented to the Institution, Nottingham Section, by R. C. Shepherd.

Introduction.

IT was with some diffidence that I accepted your invitation to give this Paper. In the first place I only received very short notice, and secondly, I felt very uncertain as to the suitability of a paper of this description for a meeting of Production Engineers. However, the opportunity to let our severest critics know something of the founding difficulties encountered in complying with their prodigious and even, at times, fastidious demands decided me to accept the invitation. I should also like to say here that this paper has been written mainly for production engineers. To any foundryman who may be present the paper will probably appear elementary, but they will, I am sure, appreciate the impossibility of making such a paper completely comprehensive. However, I hope the foundrymen will take the opportunity of raising in the discussion any point not covered.

As a preliminary, before dealing with the subject of the paper in particular, as indicated by the title, I should like to refer to the relationship between production engineers and foundry departments and also to the effect this relationship has had upon foundry progress during the last few years.

It is generally admitted that until very recent years the foundry as an engineering department was years behind its allied departments in progress and efficiency. That this state of affairs has been largely rectified in recent years is undoubtedly largely due to the new type of production engineer who has come to the fore so much since the war. The production engineer soon realised he could not give the efficiencies he wanted unless raw materials, including iron castings, were of a much improved standard and quality to what they were just after the war. The production engineer also realised that high machine shop scrap and constant breaking down on high efficiency machine tools played havoc not only with production outputs but also with the standard of the finished job. The main troubles encountered were as follows :—

Dimensional inaccuracies. These constituted nearly the worst defect to the production engineer and were due mainly to misguided savings in pattern shop costs, core making slackness, misplacement of cores by moulders and bad moulding box tackle.

31st March, 1939

This defect precluded jig and fixture machining and necessitated a lot of marking out in order to bring castings in. Where batches of castings were involved and marking out was not done, heavy scrap resulted and dislocation of production followed. This resulted in endless delays in production with consequent unfulfilled delivery promises and higher production costs. Further, interchangeability was affected causing endless recording of "specials" in the Records Department. This ultimately reacted unfavourably upon the customer and mitigated against the 100% mechanism the production engineer was striving to produce.

Blowholes. This defect caused high scrap in all stages of machining and was due to a variety of causes such as bad venting of cores and mould, unsuitable sands, bad drying conditions, badly placed or designed runners, incorrect riser and feeder practice, etc.

Internal shrinks. This defect was often not revealed until the final test pressure was applied and after all machining and often erecting costs had been incurred. It was indeed a very expensive defect. Again its cause could be one of many, but until fairly recent years most of the reasons given were mostly conjecture. The main causes of such defects are unsuitable metal, incorrect feeding, lack of chills in right place, shape of cores, bad section changes, etc.

Deliveries of small quantities to machine shops instead of either complete orders, or batches sufficient in quantity to warrant machine shops setting up for.

Excessive weight generally due to poetic licence taken by both pattern maker and foundryman.

The new production engineer began to call for castings free from these five major defects and at first he got very little response from the foundryman. His demands then began to get more and more exacting as he realised this was the only way he could get what he wanted. The latitude the foundryman had had in the past and which was always expected was then firmly and often impolitely refused. This latitude generally took the form of "humouring" on the marking out table, stopping up of blowholes and surreptitious use of sal-ammoniac for doctoring internal shrinks.

Tolerances of all sorts began to be cut down, but for a long time foundrymen declared these new demands to be impossible of attainment and many refused to the bitter end to co-operate with the production engineer; in fact, tradition died hard.

In the end, of course, the production engineer won and the foundryman gradually capitulated and began to look more closely into his job with a view to putting his house in order. Many were the obstacles encountered, and as a matter of interest I have tabulated some of the most important.

Obsolete foundry plant. Engineering shops had outstripped the foundries in new plant. The plaint was that managements had

neglected foundries' plant requirements and had in fact spent all available money on the machine shops. This, of course, was not generally true. In most cases it was the conservative foundryman himself who had been afraid to embark upon capital expenditure. His very training almost made it a matter of pride to produce castings with a minimum of tackle. In point of fact he often considered it might reflect upon his capabilities to have to ask for money for aids to produce castings. Very probably too the fear that the introduction of machines into the foundry would mean the end of foundry craftmanship as he understood it also influenced his reluctance to ask for grants for plant.

Please do not misunderstand me in regard to my views of the old type foundryman. No one could deny that most of them were enthusiastic and very efficient craftsmen. To them the production of castings with practically no tackle (and what they had was the very crudest) was the epitome of success. No doubt it was their knowledge of the enormous amount of thought and work they put into each individual job which made them so intolerant of criticism of their finished work. But only when this knowledge and experience, however, was allied with a desire to produce the job to the new standards of quality was any progress made.

Moulders' ancient tradition.

Lack of co-operation between foundry and design departments.

Unsuitable raw materials available, generally due to misguided economy.

Insufficient knowledge of best melting, sand and metallurgical practices.

Pattern shops' false economy, making it almost impossible to produce to required standard of dimensional tolerances.

New foundry plant began to creep into foundries and specialised makers of foundry plant appeared in reply to a long standing want. The American automobile foundries really set the ball rolling, followed very closely by the leading car manufacturers in this country. These foundries did an enormous amount of pioneer work and in many cases paid heavily for it in the early days. Many of the early schemes did not work too smoothly at first, and the old conservatives had plenty of opportunities of saying "I told you so." But the pioneers plodded on and by hard work and after many disappointments successful results began to be obtained. The resulting castings were remarkable for quality compared with the old hand-produced job and, to the astonishment of the old conservative, were a much cheaper job to produce under the new conditions, so that the production engineer could and did say that the "best job was the cheapest."

The ultimate success of the automobile foundries began to awaken the interest of general engineering foundries. At first the

old conservatives tried to save their faces by claiming only repetition work in large quantities could be produced by such mechanised aids, but again pioneers got busy and showed that even small quantity production could benefit by mechanical aids. Unfortunately the term " foundry mechanisation " is a loose one. Foundry mechanisation is simply the application of " improved production plant and methods " to a degree determined by the conditions involved. The old conservatives played on the looseness of the term " Mechanisation " and indeed still do. Obviously the degree of mechanisation embarked upon must depend entirely on the quantity and type of production, and this degree can only be determined by the foundry concerned, but all too often the old conservative takes it upon himself to criticise the pioneers' efforts without any knowledge of the conditions involved. The statement " We could not mechanise our plant " is often made, but these are the people who never ask themselves " Can we improve our methods of plant and production in any way to produce a better quality at a cheaper production cost?" It would certainly appear now in the light of the progress that has already been made by a large number of progressive foundries that those foundries who still resist the introduction of mechanical aids to help production and quality are asking for a slow but sure end.

Please do not misunderstand me as inferring that the day of the old jobbing foundry is finished. I believe there will always be room and also a necessity for such plants, but even here, mechanised aids can help to improve quality and to cut costs—*e.g.*, introduction of compressed air, jolt ramming machines, sand mills, efficient mould drying plant, pneumatic chipping hammers for fettling, etc., or even the application of roller conveyors here and there.

Summing up this rather lengthy introduction I hope to show to-night that modern foundries are following on the very heels of latest machine shop practice, and that in fact these latter will have to take care they are not outstripped in the race for 100% efficiency.

I now propose to deal mainly with the procedure and plant used in the manufacture of general oil engine castings in the author's foundry.

Foundry Raw Materials and their Control.

Cupola Metal Mixtures. These are made up generally from various pig irons, foundry runner and riser returns, cast iron scrap and steel. Firstly, the composition of each must be known so that the correct proportion of each can be calculated in order to ensure predetermined composition and characteristics of the molten metal at the spout.

Fuels for Melting and Drying. Coke is the foundry's main

fuel and various types are used. In all cases it is now possible to purchase to specification as the required characteristics are known and can be set down in the form of a specification. For melting purposes the main features are :—

Low ash content. Low sulphur content and pick up. High strength or shatter values. Low carbon pick up.

FOUNDRY SANDS. These are of many different types. The following gives a broad classification of some types used.

Natural bonded sands. This section alone covers many different sorts. For our purpose to-night, however, this type may be described as having a base of sand grains together with a proportion of clay varying anything from 3 to 20%. The clay is the element which bonds the grains together. After " milling," the clay forms an adhesive envelope around each grain and is thereby responsible for the property known as " green bond strength." The higher the clay content, generally, the higher is the bond. The size of the individual grains control roughly the property known as " permeability." Broadly this means porosity. The higher this value the more self-venting is the mould, the more easily can gases and air escape during the casting operation, and the less likely is it that they will be trapped in the casting in the form of " blowholes." Briefly the foundry man attempts to get the highest permeability allied with the strongest possible bond. Moisture content affects both these properties and has accordingly to be controlled within narrow limits.

Two main varieties of natural bonded sands are used—*viz.*, green sand and dry sand. The term green sand indicates that the metal is poured into an undried sand mould and dry sand indicates the mould is dried before casting ; 100% new sand is seldom used for moulding. The usual practice is for the " facing sand " to contain anything from 10 to 60% new sand, the remainder being used floor sand, plus one or more of the following : coal dust, horse droppings, sawdust, silica sand.

Facing sand means a specially milled and mixed sand which is applied to all faces of the pattern as the first operation, and the remainder of the moulding box is rammed with floor sand.

Synthetic sands. These have come very much to the fore of late to fill a want for a 100% controlled sand. As the name implies pure silica sand is used for a base to which is added the desired proportion of a colloidal clay. In this way a perfect control of bond and permeability is obtained. Synthetic sand is more expensive than natural bonded sands, and this is the reason for its somewhat limited application, but its use is growing considerably.

Cement sands. A process for bonding silica sand with cement has recently been developed. The main claims here are :—

Controlled bond and permeability.

Air-drying properties which dispense with hot stove drying in the foundry.

Making moulds of built-up cores and so dispensing with moulding box tackle.

Oil bonded sands. Here again silica sand is used as a base and various oil compounds added, and milled in, to develop the bond. The bond may also be increased by colloidal clay and/or natural bonded sand additions. The oil compounds vary considerably in constitution but are generally mixtures of one or more of the following: linseed oil, linseed oil substitutes, molasses, dextrine, flour compounds, mineral oils, resin compounds, etc. This type of sand is generally used for coremaking and usually contains from 2 to 3% oil compound. The sand possesses a very high bond strength in both the undried and dried state, and invariably a high permeability figure. The term "air drying" is another useful property possessed by certain oil sands containing dextrine. This property helps in the manufacture of intricate shaped cores where drying packers are not used. As soon as the core is stripped from the core box the surface of the core begins to air-harden and the extra strength obtained this way reduced the tendency to sag, thus helping precision working. Air drying is therefore a most important property and can be controlled within narrow limits, with care.

Sand control. The foregoing remarks will indicate the necessity of some kind of accurate control. Most modern foundries operate such a control. Sand testing apparatus is of a comparatively simple nature and it is not always necessary to have laboratory trained assistants to work it. Daily routine tests are carried out for the following properties: moisture, permeability, green and dried strength, grist or grain size tests, air drying. In the author's foundry daily tests are plotted and variations from day to day can be immediately spotted and corrected. The drying of the various types of sand is very important. A sand mould can be spoiled in the same way as a piece of steel by incorrect heat treatment. Too high a temperature drives out the combined water in the clay and results in a friable sand. Too low a temperature results in incomplete drying and the formation of steam during casting and a resulting blown casting. Drying stoves are therefore controlled by pyrometer or thermometer, usually of the recording type.

MOLD FACINGS. These are usually plumbago, blacking and coal dust.

Plumbago. In green sand work this is applied dry, being shaken on to the surface of the mould through a canvas bag known as a "dusting bag." The usual practice is for the moulder to "sleek" the dusted plumbago with either his fingers, brush or a moulder's tool until a smooth bright finish is obtained. This finish is, of course,

reproduced on the casting as the plumbago protects the surface sand from the high temperature of the molten metal.

In dry sand work the plumbago is usually applied wet by either a brush, spray or swab and serves the same purpose as in green sand work. Sometimes a bond such as clay, gum or oil compound is used in the plumbago wash to further secure the coating to the mould surface.

Blacking. This is a material usually prepared from coke oven deposited carbon or from discarded carbon electrodes. There are many varieties on the market, but mainly the property "high temperature resistance" depends upon the actual carbon content and high temperature fusibility of the ash content. It is generally used as a substitute for plumbago either wholly or partly for the purpose of protecting the sand surfaces of the mould. Unlike plumbago, however, it does not possess any "sleeking" properties and does not therefore give the smooth bright finish usually associated with plumbago. For this reason also it cannot be used for green sand work.

Coal Dust. This material is not truly a mould facing inasmuch as it is not applied to the mould faces. Usually it is mixed in with the facing sand in a proportion anything up to 5/6% for green sand work. Its purpose is to improve the skin finish of the castings. The accepted theory is that the volatile gases given off during casting form a protective envelope between the metal and the mould. Essential properties are correct volatile hydro carbon contents, a high temperature fusible ash and the correct grist or mesh to suit the casting section.

Furnace Refractories. These form a very important section of foundry raw materials. For cupolas, firebrick logs and/or gannister is used. Careful selection and control of these materials are essential to ensure low working costs. Rotary and electric melting furnaces are now being installed in a number of foundries and these call for special attention with regard to refractories. Good foundry costing should include actual cost of refractories and labour involved, per ton of metal melted, and it is surprising how the quality of refractories used affects this figure.

In concluding this section of the paper I want to emphasise the utmost importance of the careful selection and control necessary for all raw materials. This control is the first step towards the production of the 100% casting. Material, no matter how crude it may appear, can be neglected and nothing should be taken for granted when considering supplies. First cost is practically neglible compared to ultimate cost involved in producing and handling scrap castings.

Pattern Shop.

The demand for castings to conform strictly to drawing and with minimum machining allowances calls for a much more accurate type of pattern than was necessary under the old methods. The old type of patternmaker was taught to pay attention to centre lines, machined faces and bores and to make sure that there was plenty of metal thickness. The outside shapes were not important so long as they pleased the eye.

Present day practice demands accuracy on every contour. The jig designer does not often consult the foundry as to which part of the casting will provide the most accurate location and often makes his location spots on the point where there has been a false core. Frequently the whole set-up depends on the true location of a cored hole.

It would be a definite advantage if it could be stated on the drawing, before issuing to the shops, the desired location spots. Special precautions could then be taken, such as position of runner, placing of risers, etc.

Types of Patterns.

Wood patterns, large. Canadian pine is the wood usually used in the construction of large and medium patterns. Large patterns are framed up, joints either half capped or morticed together. Where possible, bolts are preferable to wood screws. Lifting straps should be built in the frame work and not allowed to project above the joint line of the pattern.

Small patterns. These are usually made in mahogany or teak. Both these woods stand either heat or damp very well. It is possible to work much more accurately in hard wood than in soft.

Composite patterns. Wood and metal mixed on patterns is not a great success. The metal parts and screws work loose and the life is not so long as that of a good hard wood pattern. Composite core boxes are a definite success. Loose metal sections in a stout frame stand up well and the cores are true to shape. One advantage of the metal inserts is that these can be used as core packers and be left in the cores during the stoving operation.

Metal patterns. These are definitely the best proposition for production. Though expensive, in the long run they are probably the most economical. No short cuts should be taken in the manufacture of these. If practicable they should be machined all over. Core prints made separate and screwed in position on machined faces are a much more accurate job than if cast in position and filed up.

Metal core boxes. These should be as light as possible, the necessary strength being added by means of ribs and brackets. Again where possible these should be machined.

Plaster patterns. There is still a definite use for these in the modern foundry, even on moulding machines. Good flasks in cast iron machined on both sides with bars cast in position are essential. The plaster must be well reinforced and the bottom side level with machined face. Delicate parts of the plaster pattern can be tipped with some kind of type metal. These tips have the necessary fastening wires cast in which fastens them to the final pattern. Plaster patterns are much cheaper than metal patterns. They have a long life even when fastened to a moulding machine table. They are cheap to make and easily repaired when worn. A plaster pattern can be in operation in the foundry eight hours after receipt of drawing.

Odd sides. These are made when a number of castings are required from a loose pattern with an irregular joint. To make a joint in sand every time is expensive. Plaster odd sides are the cheapest and possibly more accurate than wood or metal (unless the latter is machined).

Setting jigs. In coring up complicated moulds, core prints do not provide an accurate enough core location. Wooden or metal "setting jigs" are made. These are used to locate cores from inside the mould, thus ensuring correct alignment of inside with outside walls of casting.

Rubbing jigs. These are of vital importance in the core room. Core boxes are made with a plus on, to allow for "core sag." Cradles or jigs are provided in which the dried core is definitely located. The excess sand is rubbed off level with the jig top. Jig faces are usually metal faced and a steel straight edge is used to remove excess sand.

An important part of the pattern shop is the inspection department. Each pattern should be marked out with scribing block, etc., just in the same way as the resultant casting is marked out on the marking out table. Correct metal thickness is best checked by templates, one made to fit outside the pattern and one to inside of core box or boxes.

Pattern storage. The storing and registration of patterns is a very important part of a foundry organisation. Pattern stores should be divided into bays, and where racks are used, these should be sub-divided into shelves to make location more definite.

Each pattern should have identity cards in duplicate, one being kept by the pattern store keeper and one in a fire-proof safe in the pattern shop. All particulars of alterations to patterns, etc., should be on a master card held by the pattern shop. The store card will only have pattern location and dates when sent into the foundry.

Core Shop.

Here again the following remarks refer generally to the author's foundry, but references to modern core shop developments are also

included. Firstly the large core shop. Here large cores are made entirely by girls. Cast grids or core irons cut and bent to fit the particular job are used for reinforcement. Oil sand previously described is used for making the cores. Particular attention is paid to venting—*i.e.*, providing the necessary gas and air exits. For oil engine work of all descriptions oil sand cores are particularly suitable, as they collapse very readily soon after casting, and so allow the casting to contract freely without fear of hot cracking or tearing. After stripping, the cores on flat cast iron plates are dried in stoves fired with coke-fired forced draught fire boxes at a temperature of about 400°F. This operation dries out the moisture and oil compounds and a hard brick like core is obtained. Next, the core is rubbed to size in a rubbing jig, after which it is blacked and finally dried off at a temperature of above 250/300°F.

In a small core-making department the cores are made on benches and then put on to roller conveyors where they are conveyed to the continuous drying stove. Here the cores receive a ninety minutes drying period and are unloaded the opposite end on to roller conveyors feeding the core dressing department. Here the cores are trimmed, cleaned, jigged, jointed and blacked. After this operation they then proceed via another roller conveyor to a second continuous stove for the purpose of drying the jointing and blacking coating. After this operation they are inspected and then either delivered to the moulders, or sent to the core assembly department. Core assembly is a fairly recent development in general foundry work amd in my opinion has enormous possibilities where it can be applied. The principle aim is to relieve the moulder of as much responsibility as possible in setting cores in the moulds. In those particular jobs where it has been applied the number of moulder's operations and the possibilities of incorrect core settings have been considerably reduced. Obviously individual cores assembled in a fixture must result in a more accurate casting than one made by the moulder setting each core individually. Here again the degree of assembly must depend upon the job and the quantity required, but experience has shown that some degree of core assembly can be applied for a large number of jobs, particularly where castings are subsequently jig machined. Certainly, any attention given to core shop organisation is soon repaid in the standard of quality of the finished product

Melting Departments.

The most popular melting equipment for iron foundries is the cupola. A great deal of attention and research work has been carried out in recent years on cupola development. In consequence the cupola retains its well-known flexibility, whilst its efficiency has been greatly increased and the quality of the resulting metal very much improved. The main points requiring control are metal

mixtures, coke, limestone, cupola design and air blast supply. Regular analyses of the metal, slag and exhaust gases at the cupola charging door are the usual methods of control. One of the most popular cupolas is one designed and patented by the British Cast Iron Research Association. By means of special fitments the air blast can be regulated to give practically predetermined air conditions inside the cupola. Prior to the B.B. cupola exhaust gases usually contained 15/20% CO. Now this figure has been lowered to between 4/7% with consequent coke savings. Coke ratios of 14/16 to one are now commonly obtained compared to 8/10 to one previously.

Now a few words on the progress that has been made in the qualities and properties of cast iron during the last few years. Immediately after the war cast iron was generally specified soft, medium, and hard and was of two main types—*viz.*, common and cylinder ; the former being high in phosphorus and the latter low. The tensile strength varied from roughly 6/10 tons per sq. in. according to section. If (in the opinion of foundrymen) a specially good grade was required they included cold blast pig iron in the cupola mixture and obtained perhaps up to 12 tons per sq. in. in reasonable sections, but the thick sections were always open and weak. Simultaneously with foundry plant progress, metallurgical pioneer work started and progressed very rapidly. This work began to clear up many of the old shibboleths pertaining to the complex ferrous alloy known as cast iron. The fundamental weakness of cast iron having varying strengths in varying sections was nearly the first problem to be tackled and the result now is that uniform structures are obtained as an everyday occurrence in castings having very varying changes of section. This work led up to increased strengths being obtained until now there is a B.S.I. Specification, No. 786-1938 calling for tensile strengths up to 22 tons per sq. in. Such a specification indicates that high strength is being obtained at will. In fact, much higher tensiles are being regularly obtained. In our foundry, for example, up to 30 tons per sq. in. can be guaranteed in the " as cast " condition on cupola melted iron. This progress has not been due to any one individual investigator. The many individual workers have been considerably assisted by the painstaking researches of such bodies as the B.C.I.R.A., the I.B.F. Research Committees, and a number of research staffs set up and maintained by various trade interests. There is still, of course, a long way to go yet, but cast iron is certainly not the complex uncertainty it was only a few years ago. I do not intend troubling you to-night with details of the actual processes involved in the production of modern improved cast iron, but should there be any particular point or process that is of interest to anyone I shall be only too pleased to explain to the best of my ability in the

discussion. Suffice it to say that modern high strength and uniform grained cast iron has enabled many designers to cut scantlings to a considerable extent.

Sand Preparing Department.

Time will not permit a comprehensive review of all the sand-handling plant now available to foundries. The following remarks apply therefore only to the author's foundry.

Firstly, the plant used for the preparation of all the facing sands used in the heavy and medium foundries. The plant consists of a cleaning unit, comprising a rotary screen through which the screened sand drops on to a belt conveyor, the head pulley of which is a magnetic drum for removing the tramp iron. The cleaned sand is delivered to the elevator which delivers it to a large storage hopper. From this a controlled quantity can be added to the bucket loader to which also is added the new additions such as new sand, coal dust, manure, etc. The bucket loader is elevated and the contents tipped into the mill, the necessary water then added and the mixture milled together for about three to five minutes. The discharge door is then opened and the milled sand discharged on to a revolving drum having inserted pins called a disintegrator which in turn throws the finished sand into skips. This plant is known as a batch milling plant as it handles the sand in batches. There are also continuous sand plants into which the base sand and the new additions are added continuously and automatically. In the author's opinion these are not so efficient as the batch mixing type. These latter do ensure the correct admixture and thorough milling. In fully mechanised plants, however, a continuous supply of mixed sand is essential, and it is therefore necessary to make special arrangements for this if a batch mill is used. Underneath the mill is a hopper large enough to hold at least two batches. The sand is discharged from the mill into the hopper and a rotary feed table fitted with a plough, ploughs off the sand at a continuous regulated speed on to a disintegrator feeding an endless belt.

Core sand recovery is an interesting development. Such a process can only be applied where large quantities of oil sand are involved, say a minimum of 20 to 30 tons per week. The main objects in view are :—

Saving sand.
Saving dumping labour.
Conserving dumping facilities.

Briefly the process is to first rough clean the used core sand and secondly to remove as much dust and silt as possible.

Moulding Shops.

Large and medium dry and green sand castings are made in a shop having two large bays, each 600 ft. long by 50 ft. wide, equipped

with seven overhead cranes. Here, loose patterns and patterns on boards and plates are mainly handled. Such castings as housings, bedplates, flywheels, cylinder heads, liners, pistons, underbases, pump casings and impellors, all types of excavator castings, etc., are produced in these shops. Mechanical aids such as three sand slingers, large jolt ram and smaller jar ram squeeze machines are used to help production. Moulding box tackle is used almost exclusively and pit and loam moulding only used for very occasional one-off jobs. Experience has shown that moulding in boxes is generally more accurate for this class of work than pit or loam production, and is generally very much cheaper. To ensure accuracy of core location, the use of templates and jig by all moulders is insisted upon. No moulder is allowed to use his foot rule for setting purposes either as a rule or as a crude divider as used to be common practice. Each set of patterns and core boxes has its own equipment of templates, each marked up with the pattern number. This arrangement has helped very considerably to remove most of the machine shops' complaints of bad locations. Particular attention is also paid to every operation affecting soundness and surface finish and no detail is neglected which influences in any way the quality of the finished job. An enormous variety of work has to be catered for, as anything from 500 to 1,000 different patterns per week are being handled in this section alone. This variety constitutes a tremendous problem and entails endless detail supervision on the part of all foundry executives and close co-ordination between all interested sections, as it cannot be denied that the human element still plays a big part in foundry production, although everything is being done to offset its influence. Mould drying is carried out by means of eight large stoves located at convenient points round the shop. Each is heated by coke-fired, forced draught fire-boxes. Stoves are equipped with frictionless bogies. When fully loaded, two men can easily move them. Temperatures are controlled by recording thermometers on each stove.

In the Mechanised Foundry where the smaller details are produced in quantities varying mainly of batches from twelve off to 250 off the mixed and often small quantity batch production constitutes the main problem in considering the design and layout of the department.

This and other difficulties have, however, been eventually overcome, and the result now is a very successful production department. An overhead belt deliveres prepared sand to hoppers located over eight moulding machines where the batch production moulds are made and to two-hand ramming stations where the oddments are made. After ramming, each half mould is placed on a short length of roller conveyor, cored and closed. From here the moulds are slid on to a plate conveyor, which proceeds intermittently to the casting

station. Metal is tapped from a small cupola at the rate of 2 tons per hour into a receiving ladle and from this the special pouring ladles are filled. These have a capacity up to 5/6 cwts. and each is operated by one man by means of an air hoist running on an overhead mono-rail. This method of casting takes away all the hard slaving usually associated with the casting operation. The filled moulds then proceed to knock out where they are pulled off. The sand drops through a grid and is returned to the sand preparing plant, via a cleaning unit consisting of a magnetic separator, screen and silt extractor. From the sand mill, the sand is again discharged on to the distributing belt feeding the overhead moulding machine hoppers. The moulding boxes are returned from the knock out to the moulding machines by means of gravity roller conveyor. The castings are put on to a slat conveyor and discharged into tubs which in turn are taken by an overhead telpher to the fettling shop.

At the other end of the shop a sand slinger plant has been installed and can be used for the larger sized green sand oddments or for batch production of medium sized work. A sand spillage arrangement exists for returning spilt sand to the slinger feed. Closed moulds are cast up on a roller conveyor linked up with the main system.

Fettling Shop.

Large castings are delivered here by means of rail trucks. On arrival the cores are removed by hand, the sand being recovered as previously described. They are then shot blasted in a large modern air conditioned room plant, the same cascading separation as used in the core shop band recovery plant being employed for separating the shot from the sand. This plant serves two bays. Two frictionless bogies, one in each bay, allows for almost continuous operation. Whilst one bogie load is being blasted the other is being unloaded and reloaded ready to be pushed into the room when emptied. After blasting, this type of casting is trimmed by fettlers by means of compressed air chipping hammers and by electric high speed rotary grinders. After fettling each casting is individually inspected and defects are immediately reported to the responsible executive so that immediate action can be taken to avoid a repetition of the trouble.

Small castings made in the mechanised foundry are delivered to the fettling shop by telpher and tipped at the end of a belt conveyor on to which they are individually loaded by hand and fed into a continuous rotary shot blast machine. The blasted castings are automatically discharged continuously from the blast machine into a heap on the floor. Castings are then loaded into trays on a length of roller conveyor feeding the grinding wheels. From the wheels

castings are thrown into wooden troughs where they are picked up by hand fettlers. After fettling they are slid down an incline for the inspection operation. Next all castings passing inspection are loaded on to bogies and delivered to the despatch section. Certain castings are diverted here for paint dipping. This operation is confined mainly to castings intended for delivery to machine shops stores stock department and saves a lot of hand painting there.

Casting Orders, Progress and Costing.

Upon receipt of an order the delivery date required is noted and arrangements made to comply, taking into consideration previous commitments. In a large foundry producing a great variety of castings, including a great number of one to twelve off orders, a system must be devised to give absolute control of each order and to indicate its actual condition and position at a moments notice. Progress men keep the orders flowing through the shops and also arrange for delivery of cores to machines, so that there is no delay in moulding machine production.

Foundry costing has received a lot of attention recently and particularly by the I.B.F. who have appointed a Technical Sub-Committee to deal with this matter. It is recommended that each casting is costed individually so that it carries its correct share of the overhead charges. The main items to be arrived at are :—

Cost of metal at the spout. Items considered here are cost of pig, scrap, alloys if any, and metal losses, plus the indirect charges such as labour, fuel, limestone, refractories, power, etc., and all the standard indirect charges.

Moulding and core making costs. Actual direct charges for these items are the actual labour cost or the piece-work prices. The indirect charges should vary with the method of production—*e.g.*, distinction being made between machine and hand-made moulds, and also hand and machine made cores, etc., the charges being fixed accordingly. Typical indirect costs in these sections are, indirect labour, sand, chaplets, sprigs, fuel, core oils, mould facing materials, etc.

Fettling department costs. Here it is more convenient to base direct costs on a tonnage basis instead of individually. Castings are graded and a different price per ton paid for each grade. All castings are shot blasted and a separate price per ton paid for this operation. Other main items which must be ascertained are : Percentage of rejects to castings delivered. Percentage of castings to metal melted. Ratio of iron melted to coke used.

Casting Inspection. This is an important position and amiable relations between foundry and machine shops depend largely on the type of man chosen. Possibly a pattern maker with a suitable personality and qualifications is the ideal man for the job. His knowledge of drawings, pattern making and foundry practice should enable him to locate the fault and put the blame in the proper quarter. His report to the management should be without fear or favour.